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Impact of Uncertainty on Terror Forecasting

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Introduction: Intelligence analysts and military planners need accurate forecasting techniques for predicting future terror events. Terror forecasts must consider historical events, up-to-date geospatial features, terrorist behavior, and uncertainty and error in the input measurements and propagation of data. We describe our forecasting technique and investigation of the impact of uncertainty and error on predicting future terror events.

Forecasting Technique: We have developed innovative geospatial analysis and asymmetric-threat forecasting techniques for urban environments.[1,2] The foundation of our techniques is the extraction of behavior "signatures" from associations made between information sources (for example, historical event data, sensor data, etc.) and contextual information sources (for example, geospatial and time-based demographic, economic, and political databases). The technique assumes that a terrorist's or criminal's choice of a certain location is influenced by a set of qualities such as geospatial features, demographic and economic factors, and recent political events.[3] Focusing on geospatial information, we assume that the intended target is associated with the features located within a small distance from the event location. Furthermore, we consider the distance between key features and the event location as defining a likelihood function maxi-

mizing the values at distances common to the greatest number of events. The spatial likelihood functions are used to generate a choropleth map (a map showing differences between regions by using shading or coloring). A sample forecast for likely suicide attacks by militants in Haifa is shown in Fig. 1(a).

Inclusion of Uncertainty: Forecasts not accounting for uncertainty in the input measurements potentially mislead planners into allocating security resources to protect lower-value targets. Uncertainty and error of data play a role throughout the complete process of generating terror forecasts, ranging from data collection to generation of spatial likelihood functions to presentation of the forecasts. By working with a field expert and surveying the literature we generated a table of these factors. We preliminarily categorized the factors by: (1) *building databases* — event data collection, feature data selection, and data confidence assessment; (2) *generating forecasts* — data retrieval and transformation, uncertainty modeling, probability density function (PDF) generation, and likelihood layer aggregation; and (3) *data presentation* — data preparation, forecast visualizations generation, and user interface. We made a list of variables and values that fit into each category, some of which propagate throughout all layers of the table hierarchy. Currently, we are ranking the factors by how much they contribute to change in the forecasts.

Testing Uncertainty Impact: We investigated the impact that uncertainty has on forecasting by testing a small set of the uncertainty factors from our table. Here we highlight one experiment testing error in the
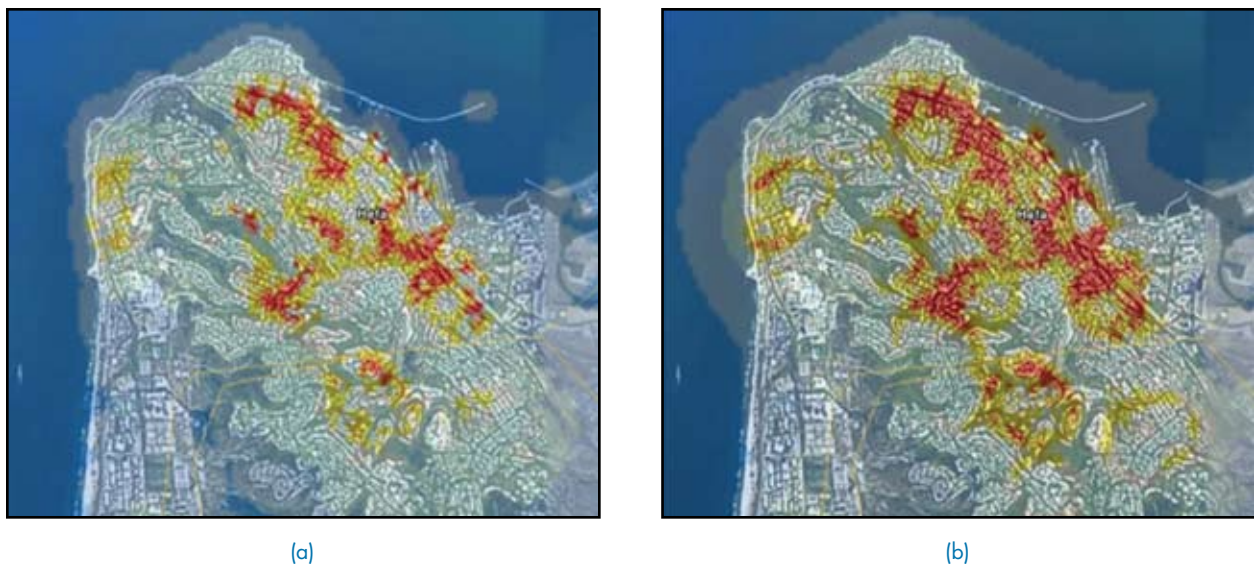

(a)

(b)

FIGURE 1
(a) Choropleth map showing threat "hotspots" color-coded by likelihood — red represents highest likelihood. (b) Inclusion of historical event position uncertainty by Monte Carlo simulation.

position of the historical event recordings. Our datasets include historical information pertaining to suicide bombings such as date, time, responsible faction, event position, and confidence. These confidence values, ranging from 1 to 5, correspond to a uniform distribution of error in the reported event position with values starting at 10 m and increasing radially by a power of 10 for each rank as assigned by analysts sorting through text descriptions of the events with information like "*event X occurred in the doorway of a club while event Y occurred somewhere within a settlement.*" We incorporate the event position uncertainty using a Monte Carlo simulation technique that perturbs the event location within its confidence radius. Since the distance between the event position and feature of interest varies upon each iteration of the simulation, the likelihood values for a given geo-coordinate are aggregated. We stop the Monte Carlo simulation when the coefficient of variation — a minimal number of iterations that indicates statistical significance has been achieved — is reached.[1]

Starting simply, using a one-layer Geographic Information System (GIS) feature set consisting of locations of gas stations, the distance associated with the maximum likelihood of a suicide bombing event for a specific faction is about 0.5 km when uncertainty is not included. As the radius of uncertainty increases, the maximum likelihood distance increases by up to 0.4 km (see Fig. 2). This effect, though negligible on a coarse grid, is significant for neighborhood-scale forecasting where the predicted "hotspots" may shift several blocks (see Fig. 3). As the number of GIS layers increase, the uncertainty propagates and a very different surface results.

Conclusions: Our forecasting techniques excel at reducing the search area required and maximizing the placement of resources (for example, sensors, troops, and intelligence operators). Versions of our forecasting techniques are already in use by intelligence analysts and military planners within the Department
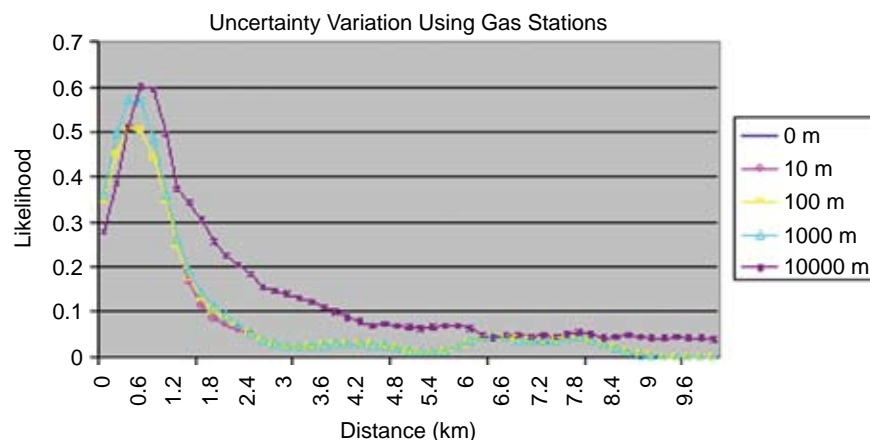

FIGURE 2
The PDFs generated for uncertainty levels of 0, 10, 100, 1000, and 10,000 m. The distance of the maximum likelihood increases and the PDFs become less defined as the uncertainty increases.
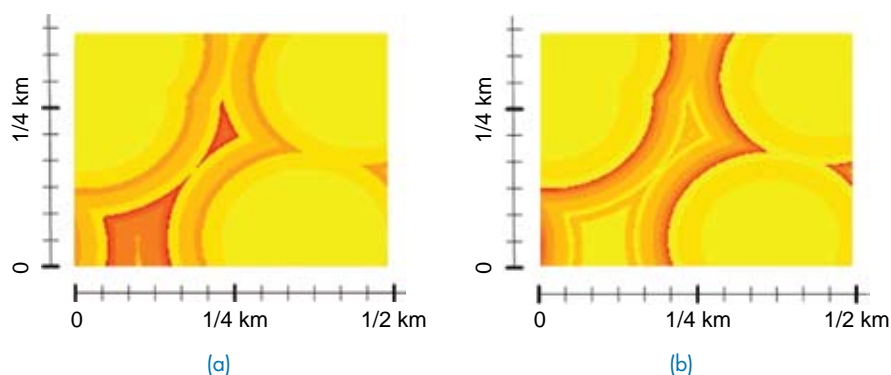

FIGURE 3
Two likelihood surfaces generated for a neighborhood in Jerusalem. (a) No uncertainty is factored in. (b) Includes variation in the event position up to 10 km. The red "hotspots" (maximum likelihoods) have moved to entirely new locations.

of Defense and the Department of Homeland Security to narrow the search space for high value individuals. Our initial investigations of the impact uncertainty has on the forecasts indicate: (1) the likelihood values shift a reasonable amount for moderate changes in data parameters (though we need to perform more parameter sensitivity tests), and (2) the range of threat "hotspots" increases and will need to be filtered in order to comply with the goals of the forecasts — reducing the search area. We conclude showing the latter case — incorporating event position uncertainty in the Haifa region — in Fig. 1(b).

[Sponsored by OSD]

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